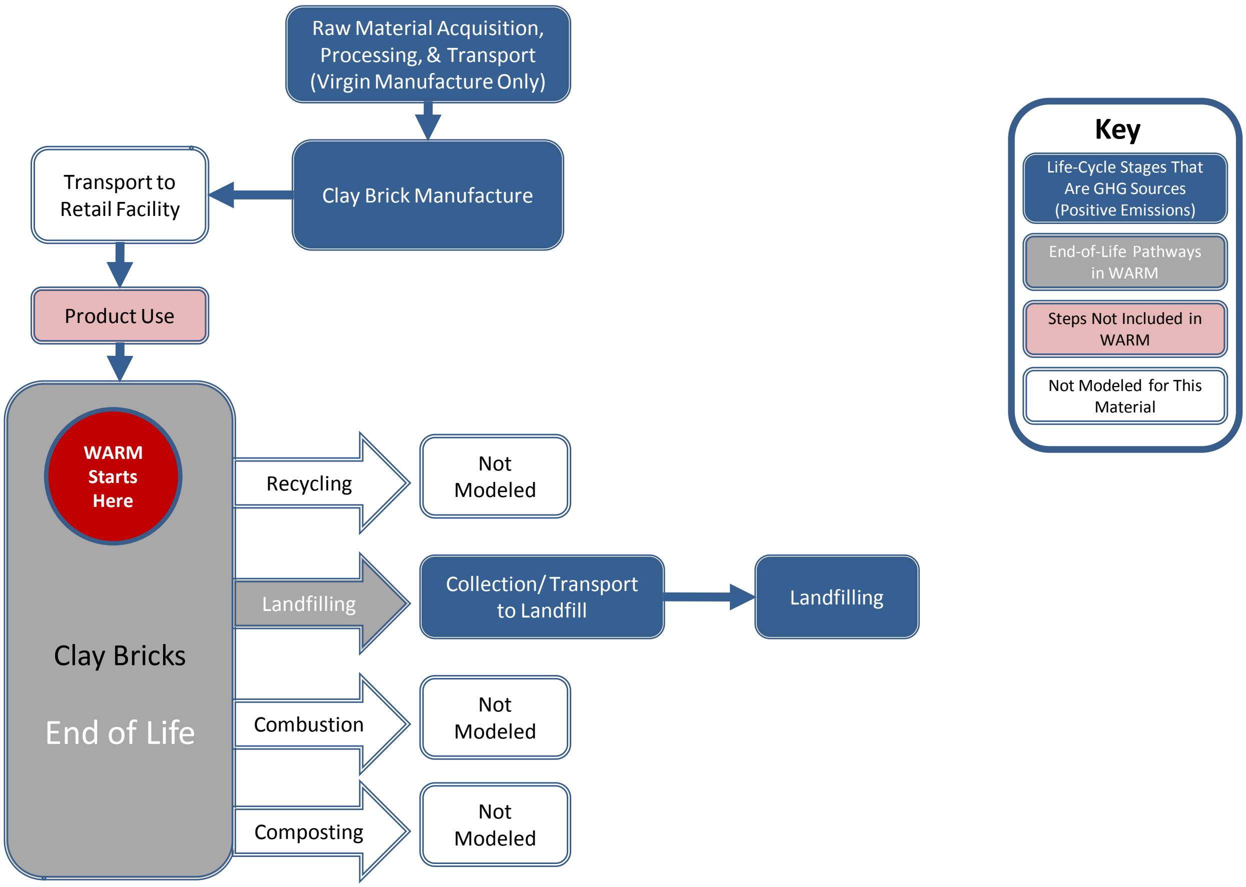
CLAY BRICKS

1. INTRODUCTION TO WARM AND CLAY BRICKS

This chapter describes the methodology used in EPA's Waste Reduction Model (WARM) to estimate streamlined life-cycle greenhouse gas (GHG) emission factors for clay bricks beginning at the point of waste generation. The WARM GHG emission factors are used to compare the net emissions associated with clay bricks in the following waste management alternatives: source reduction and landfilling. Exhibit 1 shows the general outline of materials management pathways for clay bricks in WARM. For background information on the general purpose and function of WARM emission factors, see the Introduction & Overview chapter. For more information on Source Reduction and Landfilling, see the chapters devoted to these processes. WARM also allows users to calculate results in terms of energy, rather than GHGs. The energy results are calculated using the same methodology described here but with slight adjustments, as explained in the Energy Impacts chapter.

Exhibit 1: Life Cycle of Clay Bricks in WARM



Most clay bricks are produced by firing common clay and shale in a kiln, although other types of clay, such as kaolin and fire clay, are also sometimes used (Virta, 2009). Of the 5.4 billion bricks produced in the U.S. in 2008, the majority were clay, accounting for 60 percent of annual production, or approximately 3.3 billion bricks (U.S. Census Bureau, 2010).

Clay bricks can be salvaged and reused, enabling source reduction of virgin clay bricks. It may also be possible to recycle broken or damaged clay bricks during the manufacturing process, although EPA did not locate sufficient data to model a recycling pathway for management of clay bricks. Because clay bricks are inert and non-combustible, they cannot be composted or incinerated for energy recovery.

2. LIFE-CYCLE ASSESSMENT AND EMISSION FACTOR RESULTS

The streamlined life-cycle GHG analysis in WARM focuses on the waste generation point, or the moment a material is discarded, as the reference point, and only considers upstream GHG emissions when the production of new materials is affected by materials management decisions.[1] For most materials, recycling and source reduction are the two materials management options that impact their upstream production and consequently are the only pathways that include upstream GHG emissions. Since WARM does not evaluate a recycling pathway for management of clay bricks, source reduction is the only pathway that affects upstream GHG emissions from clay bricks. For more information on evaluating upstream emissions, see the chapters on Recycling and Source Reduction.

As Exhibit 2 illustrates, the GHG sources relevant to clay bricks in this analysis are contained in the raw materials acquisition and manufacturing portion and end of life portions of the life cycle. WARM does not evaluate recycling, composting or combustion as life-cycle pathways for clay bricks because recycling is not a common practice and the data on recycling of clay bricks are limited, and clay bricks cannot be combusted or composted.

Exhibit 2: Clay Bricks GHG Sources and Sinks from Relevant Materials Management Pathways

Materials Management Strategies for Clay Bricks	GHG Sources and Sinks Relevant to Clay Bricks		
	Raw Materials Acquisition and Manufacturing	**Changes in Forest or Soil Carbon Storage**	**End of Life**
Source Reduction	**Offsets** • Transport of raw materials and products • Virgin manufacture process energy • Virgin manufacture process non-energy	NA	NA
Recycling	Not applicable because clay bricks are not commonly recycled		
Composting	Not applicable because clay bricks cannot be composted		
Combustion	Not applicable because clay bricks cannot be combusted		
Landfilling	NA	NA	**Emissions** • Transport to landfill • Landfilling machinery

NA = Not applicable.

3. RAW MATERIALS ACQUISITION AND MANUFACTURING

GHG emissions associated with raw materials acquisition and manufacturing (RMAM) are: (1) GHG emissions from energy used during the acquisition and manufacturing processes, (2) GHG emissions from energy used to transport raw materials, and (3) non-energy GHG emissions resulting from manufacturing processes.[2] For clay bricks, process energy GHG emissions result from acquiring the raw clay used in manufacture and the firing process used to produce clay bricks. Transportation emissions are generated from transporting raw materials to the brick manufacturing facility. EPA

[1] The analysis is streamlined in the sense that it examines GHG emissions only and is not a comprehensive environmental analysis of all emissions from materials management.

[2] Process non-energy GHG emissions are emissions that occur during the manufacture of certain materials and are not associated with energy consumption.

assumes that non-energy process GHG emissions are negligible because no data source consulted indicated the presence of these emissions.

In general, RMAM calculations in WARM also incorporates "retail transportation," which includes the average truck, rail, water and other-modes transportation emissions required to transport a material or product from the manufacturing facility to the retail or distribution point. However, the emissions associated with retail transport of clay bricks are assumed to be zero/not modeled in WARM because no suitable data on retail transportation of clay bricks was available at the time of creating this emission factor.

4. MATERIALS MANAGEMENT METHODOLOGIES

WARM evaluates GHG sources and sinks from source reduction and landfilling of clay bricks. Exhibit 3 provides the net GHG emissions per short ton of clay bricks for each of these materials management pathways. Source reduction avoids GHG emissions because it offsets emissions from manufacturing processes and transportation of raw materials. Landfilling results in GHG emissions from transporting clay bricks to the landfill and operation of landfill equipment. More details on the methodologies for developing these emission factors are provided in sections 4.1 through 4.5.

Exhibit 3: Net Emissions for Clay Bricks under Each Materials Management Option ($MTCO_2E$/Short Ton)

Material/Product	Net Source Reduction (Reuse) Emissions For Current Mix of Inputs	Net Recycling Emissions	Net Composting Emissions	Net Combustion Emissions	Net Landfilling Emissions
Clay Bricks	-0.28	NA	NA	NA	0.04

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
NA = Not available.

4.1 SOURCE REDUCTION

When a material is source reduced (i.e., less of the material is made), GHG emissions associated with making the material and managing the postconsumer waste are avoided. In WARM, source reduction of clay bricks involves reusing old bricks that have been salvaged at end of life. Because reused bricks may lack the strength and durability of new bricks, the reuse of bricks is not appropriate for all brick structures. This is why the U.S. Green Building Council (USGBC) recommends that reused bricks not be used in exterior structures in cold climates, as cold temperatures can exacerbate existing weaknesses in reused bricks (Webster, 2002). Clay bricks are sometimes reused in such decorative or non-structural applications as brick fireplaces, hearths, patios, etc.[3]

As discussed previously, under the measurement convention used in this analysis, source reduction for clay bricks has negative raw material and manufacturing GHG emissions (i.e., it avoids emissions attributable to production) and zero end-of-life management GHG emissions. The overall source reduction emission factors for clay bricks are shown in Exhibit 4.

[3] The qualities of reused bricks are therefore not necessarily "functionally equivalent" to those of new bricks, since they cannot be used in all of the same applications. WARM does not account for this in the source reduction emission factor since the model assumes that reusing clay bricks for non-structural purposes would still offset the production of new virgin bricks.

Exhibit 4: Source Reduction Emission Factor for Clay Bricks ($MTCO_2E$/Short Ton)

Material /Product	Raw Material Acquisition and Manufacturing for Current Mix of Inputs[a]	Raw Material Acquisition and Manufacturing for 100% Virgin Inputs	Forest Carbon Storage for Current Mix of Inputs	Forest Carbon Storage for 100% Virgin Inputs	Net Emissions for Current Mix of Inputs	Net Emissions for 100% Virgin Inputs
Clay Bricks	-0.28	-0.28	NA	NA	-0.28	-0.28

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
[a]: For this material, information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the "current mix of inputs" and "100% virgin inputs" are the same.
NA = Not applicable.

Because EPA assumes that clay bricks are always produced from 100 percent virgin materials, the GHG emission factor for "100 percent virgin inputs" is equal to the factor for the "current mix" of virgin and recycled inputs. Post-consumer emissions are the emissions associated with materials management pathways that could occur at end-of-life. When source reducing carpet, there are no post-consumer emissions because production of the material is avoided in the first place, and the avoided carpet never becomes post-consumer. There are no changes in forest carbon storage since clay bricks contain no paper or wood and therefore do not influence forest carbon stocks. For more information on this topic, please see the chapter on Source Reduction.

4.1.1 Developing the Emission Factor for Source Reduction of Clay Bricks

The approach and data sources used to calculate the emission factor for source reduction of clay bricks are summarized below for each of the three categories of GHG emissions: process energy (pre-combustion and combustion), transportation energy and process non-energy emissions.

Avoided Process Energy Emissions: Process energy GHG emissions result from both the direct combustion of fossil fuels and the upstream emissions associated with the production of fuels and electricity (i.e., "pre-combustion" energy).[4] An estimated 5.1 million Btu of total energy are required to produce one ton of clay bricks (Athena, 1998).[5] To calculate process energy emissions, we determine the national-average mix of fuels used to manufacture clay bricks. We then multiply the amount of each fuel consumed by the fuel's GHG emissions intensity (i.e., GHG emissions per Btu of fuel consumed) to obtain CO_2 and CH_4 emissions for each fuel (EPA, 2011). Total process energy GHG emissions are calculated as the sum of GHG emissions, including both CO_2 and CH_4, from all of the fuel types used in the production of one ton of clay bricks. Results of these calculations are provided in Exhibit 5.

Exhibit 5: Process Energy GHG Emissions Calculations for Virgin Production of Clay Bricks

Material/Product	Process Energy per Short Ton Made from Virgin Inputs (Million Btu)	Process Energy GHG Emissions ($MTCO_2E$/Short Ton)
Clay Bricks	5.10	0.28

Avoided Transportation Energy Emissions: Transportation energy emissions occur when fossil fuels are used to transport raw materials and intermediate products for clay brick production. The methodology for estimating these emissions is the same as the one used for process energy emissions. Total transportation energy emissions are calculated based upon an estimate of total clay brick

[4] "Pre-combustion" emissions refer to the GHG emissions that are produced by extracting, transporting, and processing fuels that are in turn consumed in the manufacture of products and materials.
[5] This total represents the sum of pre-combustion and combustion process energy.

transportation energy and the corresponding fuel mix (Athena, 1998) and using fuel-specific coefficients for CO_2 and CH_4 (EPA, 2011). The related GHG emissions are provided in Exhibit 6.

Exhibit 6: Transportation Energy Emissions Calculations for Virgin Production of Clay Bricks

Material/Product	Transportation Energy per Short Ton Made from Virgin Inputs (Million Btu)	Transportation Energy GHG Emissions ($MTCO_2E$/Short Ton)
Clay Bricks	0.03	0.00

Note: The transportation energy and emissions in this exhibit do not include retail transportation.

Avoided Process Non-Energy Emissions: No process non-energy emissions take place during the manufacture of clay bricks. Hence, there are no avoided emissions.

4.2 RECYCLING

When a material is recycled, it is used in place of virgin inputs in the manufacturing process, rather than being disposed of and managed as waste. Research indicates that there is very little postconsumer recycling of bricks (Athena, 1998). Likewise, almost all bricks in the United States are made from virgin materials, so EPA has not analyzed the impacts of using recycled material in brick manufacture.[6]

4.3 COMPOSTING

Clay bricks are not subject to aerobic bacterial degradation and cannot be composted. Consequently, WARM does not include an emission factor for the composting of clay bricks.

4.4 COMBUSTION

Clay bricks cannot be combusted; consequently, WARM does not include an emission factor for the combustion of clay bricks.

4.5 LANDFILLING

In general, GHG impacts from landfilling consist of landfill CH_4 emissions; CO_2 emissions from transportation and landfill equipment operation; landfill carbon storage; and avoided utility emissions that are offset by landfill gas energy recovery. However, because clay bricks do not contain carbon-based materials or degrade in landfills, they do not produce CH_4 emissions or result in carbon storage in landfills. Therefore, the landfilling emission factor only accounts for transportation emissions: transportation of clay bricks to a landfill and operation of landfill equipment result in anthropogenic CO_2 emissions, due to the combustion of fossil fuels in the vehicles used to haul the wastes. This information is summarized in Exhibit 7. For more information on this topic, please see the chapter on Landfilling.

Exhibit 7: Landfilling Emission Factor for Clay Bricks ($MTCO_2E$/Short Ton)

Material/ Product	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Storage	Net Emissions (Post-Consumer)
Clay Bricks	–	0.04	–	–	–	0.04

[6] Athena (1998) describes the recycling of old clay bricks as feasible but not widely practiced at this time. Athena also notes that 4 to 8 percent of the volume of raw materials used in brick production is made up of damaged, finished ware that has been recycled back into raw materials. Because these inputs reflect pre-consumer recycling, not post-consumer recycling, the energy associated with manufacturing brick with these inputs would still be considered "virgin" in our nomenclature. Based on the information provided by Athena, it appears that there is very little (if any) recycled-content brick being produced. Therefore, this analysis assumes that virgin production is the same as production using the current mix (nearly 100 percent virgin inputs).

– = Zero emissions.

5. LIMITATIONS

Although this analysis is based upon best available life-cycle data, uncertainties exist in the final emission factors. Certain limitations to this analysis are outlined below:

- This life-cycle analysis does not evaluate recycling as a possible pathway because of a lack of information about this infrequent practice. Data and information about recycling processes for clay bricks, energy use and GHG emissions would be extremely helpful in analyzing and developing an emission factor for recycling as a materials management strategy.
- The source reduction emission factor could be improved through better information regarding potential reuses of clay bricks.
- Retail transport emissions for clay bricks are not currently included in the RMAM emissions factor. They could be added in the future if a suitable proxy were found.
- The data used to develop the emission factors are more than a decade old. The emission factors have the potential for improvement if EPA were to find more recent life-cycle data for clay bricks.

6. REFERENCES

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